Development of an Ocean Model for COAMPS

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LONG-TERM GOAL

The long-term goal is to develop a fully coupled, mesoscale, atmosphere-ocean prediction system that can be used over any given area of the world. This goal is to be accomplished by coupling a full-physics, mesoscale ocean model to a mesoscale atmospheric forecast model; developing, testing, and evaluating software for the necessary supporting infrastructure; and by leveraging related programs to develop an ocean data assimilation capability. This prediction system will be the cornerstone of a vertically integrated program such that it will be used for basic and applied research to study forecast problems in which coupling may be important and it will also be transitioned to operations to address those situations in which coupling is found to make a significant positive impact on mesoscale forecasts of the atmosphere and/or ocean.

OBJECTIVES

The main objectives of this project are to:

1. *Study the methodologies for, and the impact of, coupling a mesoscale ocean data assimilation system to a mesoscale atmospheric data assimilation system.* This will include studies of issues that include, but are not limited to: one-way vs. two-way interaction, frequency of coupling, and the relative importance of air-ocean energy exchanges between the atmosphere and the ocean.

2. *Test and validate the coupled prediction system over a number of areas and over a variety of atmosphere/ocean phenomena.* The purpose of this testing will be to establish under what conditions coupling is important, and whether the systems need to be loosely- or tightly-coupled. Furthermore, we will establish performance metrics to measure the quality of the atmosphere and ocean analyses and forecasts.

3. *Develop techniques to ensure that the coupled ocean-atmosphere system is relocatable to any region over the world.* Currently, the uniqueness and slope of the bathymetry for any given area; the availability of data, particularly synthetic observations; and the lack of a full-physics global model present the largest problems in relocating a mesoscale ocean model to any given location.

4. *Develop techniques to allow for a mesoscale ocean model to incorporate tendencies from a global ocean model.* The techniques that have been developed and used successfully to allow atmospheric global forecast tendencies to be used in atmospheric mesoscale models will be applied to the ocean models.

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APPROACH

Our approach is to build on the infrastructure that already exists in the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS). The atmospheric component of COAMPS has reached a level of maturity such that it is routinely used for numerous basic and applied research topics as well as for operational mesoscale forecasts. The atmospheric component of COAMPS contains complex data quality control; a multivariate optimum interpolation analysis (MVOI) capability for winds and heights; model initialization; and a nonhydrostatic, multi-nested forecast model. It has been applied for a wide range of scales, using resolutions varying from approximately 100 km to under 1 km. In a related program, a 3-dimensional MVOI analysis has been developed to construct analyses of the ocean temperature, salinity, currents, sea surface height, and ice. Inherent in this analysis program are quality control algorithms to screen the observations for errors, inconsistency, etc. In another related program at NRL SSC, the Navy Coastal Ocean Model (NCOM) has been developed for use as a regional/mesoscale ocean model. NCOM is a hydrostatic ocean model that predicts the circulation and thermodynamic properties of the ocean using either sigma-levels, z-levels, or a combination of sigma- and z-levels. The 3D ocean MVOI and NCOM will be the building blocks for the COAMPS ocean data assimilation system.

The first component of our work is to generate appropriate atmospheric forcing fields (e.g., surface stress, sensible and latent heat fluxes) with the highest horizontal resolution possible (5-27 km, depending on the area to cover and the computational resources available), to use for the upper boundary condition of the ocean model. These fields will be generated through the use of the atmospheric component of COAMPS to construct reanalyses over areas in which we will be testing the ocean model. The reanalyses will provide a continuous set of forcing fields for an extended period of time (1 year or more, depending on available computational resources). The reanalyses will be based on a 12 hour data assimilation cycle. Forecast fields will be output with a frequency of 1 hour or less. A statistical measure of the quality of the forecasts will be performed. This data will be used to compare with similar measures of atmospheric forecasts generated in future two-way coupled experiments, to measure the effect of two-way coupling on the atmospheric forecasts.

The second component of our work in this project involves using the 3D MVOI and NCOM in COAMPS and developing and testing the coupling of these components to the existing COAMPS atmospheric data assimilation system. Our studies will include one-way vs. two-way interaction, frequency of coupling, appropriate horizontal resolutions, etc., and will address such questions as: what effect do temporal changes of ocean temperature, salinity, and currents have on the short-term evolution of the atmosphere, what effect do mesoscale circulations have on the ocean structure, and what effect do ocean waves play on the atmospheric wind? The results of this work will lead to a determination of the most appropriate methodology to use, under what conditions is coupling necessary, and documentation of the impact that a coupled mesoscale system would have on forecasts of the atmosphere and the ocean.

Our initial focus will be on the Mediterranean Sea. There are several reasons for this choice: (1) it is an important area for the U. S. military, (2) it is nearly an entirely closed basin, minimizing the need for lateral boundary conditions, (3) there are frequent periods of strong atmospheric forcing due to forced mesoscale wind features (e.g., mistral, levante, bora), and (4) there exists an abundance of data for atmospheric validation. Although there is sparse sub-surface data available in the Mediterranean Sea (common to all ocean areas), there have been a number of modeling and observational studies in the past that can be used for guidance in our work. We will work in other areas of the world to demonstrate the relocatability of the coupled system and to demonstrate a wider range of phenomena that the system can be used for. In particular, we look to develop high resolution atmospheric reanalyses for the west coast of the United States and work with the Naval Postgraduate School in studying the effects of coupling in this area, which is characterized by strong upwelling. We also look to extend the testing to the Sea of Japan and the Baltic Sea, in conjunction with field experiments that are being conducted in those regions. We will look to use as many additional special datasets (i.e., those not routinely available in near-real time) as is practical, for our demonstration and verification studies.

WORK COMPLETED

1. Built the infrastructure for the COAMPS atmospheric reanalyses. Two reanalyses were started for the Mediterranean, the first using 81/27 km nested grids and the second using 36/12 km nested grids. A reanalysis for the eastern Pacific was started using 81/27/9 km nested grids. All reanalyses have a starting time of 1 Oct 1998.
2. Began development of pre- and post-processing software to enable the global relocatability of the fully-coupled COAMPS.
3. Began the following sensitivity testing of NCOM:
    a. Study the effect of the slope of the bathymetry on the NCOM solutions when using sigma-levels.
    b. Test the ability of NCOM to replicate the observed circulation of the Mediterranean Sea using large-scale atmospheric forcing over a 5-10 year time period.
4. Implemented the ocean 3D MVOI code into the COAMPS configuration management system.
5. Began forcing NCOM with fields from the COAMPS reanalysis project described in (1).
6. Began data assimilation cycling experiments using NCOM forecasts for the first-guess fields in subsequent 3D MVOI ocean analyses.
7. Completed preparation of publications on previous work on coupled air-ocean effects on tropical cyclones and tropical squall lines.

RESULTS

The atmospheric reanalyses indicate that more accurate spatial and temporal variations are predicted by using the high-resolution grids used in this study, as opposed to results found with coarser grid models. Resolutions of 27 km and less capture many local low-level wind phenomena, such as topographically-forced winds, and winds driven by differences across the land-sea boundary and diurnal effects.

Studies indicate a need for selective smoothing of the bathymetry field used in NCOM when using the sigma vertical coordinate, rather than the z-coordinate, with the current formulation of the pressure gradient force. Long-term forcing suggests that NCOM can simulate many of the observed features found in the Mediterranean.

IMPACT/APPLICATIONS

The development of a fully-coupled atmosphere-ocean prediction system is considered to be the cornerstone for studies of air-ocean research. An analogy can be drawn to the development of the atmospheric component of COAMPS. This system is now used for a variety of basic research topics, such as topographic flows, fetch-limited flows, littoral phenomena, and convection. COAMPS is also used for applied research, including real-time forecasts for field experiments such as COAST, CALJET, and LABSEA. In addition, COAMPS has been transitioned to the Fleet Numerical Meteorology and Oceanography Center (FNMOC) for operational mesoscale forecasts for four areas over the globe. It is expected that the development of a fully-coupled atmosphere/ocean COAMPS in this program would enable an expansion of the types of mesoscale studies that can be done in 6.1, an expansion of the 6.2 applications of the system, and improved operational mesoscale forecasts. The use of fully-coupled atmosphere-ocean prediction systems will not come without a price. The addition of a full-physics ocean model to the existing COAMPS atmospheric model approximately doubles the required memory and increases the total time to complete a given forecast by approximately 15%.

The COAMPS reanalyses will have a significant impact in the studies of air-ocean coupling. Fields with such high-frequency time and space variations over such a long time period (> 1 year) have never been used before in forcing ocean models. Our studies will reveal the importance of these mesoscale variations on the ocean circulation and thermodynamic structure.

TRANSITIONS

The results and data that we generate as part of this program will be used by others. The fields from our reanalyses over the eastern Pacific will be used by scientists at NRL SSC and at the Naval Postgraduate School within their joint National Oceanographic Partnership Program, to study air-ocean coupling processes on the west coast of the United States. Also, the addition of an ocean component of COAMPS could be included in our cooperative research with universities (e.g., University of Oklahoma) and other agencies (e.g., Lawrence Livermore National Laboratory, Central Intelligence Agency, Defense Threat Reduction Agency) that we currently support with the atmospheric component of COAMPS.

RELATED PROJECTS

The fully-coupled COAMPS will be used in related 6.1 projects within PE 0601153N, that include studies of fetch-limited and orographic flows, and in related 6.2 projects within PE 0602435N that focus on the development of the atmospheric components (QC, analysis, initialization, and forecast model) of COAMPS. The fully-coupled COAMPS will eventually be used in 6.4 projects within PE 0603207N that focus on the transition of COAMPS and TAMS/RT (Tactical Atmospheric Modeling System/Real-Time) to FNMOC, and the transition of the ocean data assimilation system for COAMPS.

PUBLICATIONS

Hodur, R. M., and J. D. Doyle, 1999: The Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS). *Coastal and Estuarine Studies*, American Geophysical Union, 523 pp.

Hong, X., S. Raman, R. M. Hodur and L. Xu, 1999: The mutual response of the tropical squall line and the ocean, *Pure and Applied Geophysics*, v155, No 1, 1-32.

Hong, X., S. W. Chang, S. Raman, L. K. Shay and R. M. Hodur, 1999: The interaction between hurricane Opal (1995) and a warm core eddy in the Gulf of Mexico. *Monthly Weather Review* (in press).

Hong, X., S. Raman, R. M. Hodur and L. Xu, 1999: The Mutual Response of the Tropical Squall Line and the Ocean. *Pure and Applied Geophysics* (PAGEOPH). **155**, 1-32.